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## ANGLE-RESOLVING ANTENNA SYSTEM

### Background Information

Pulse radar systems are commonly used for the determination of the speed and distance of objects in street traffic (WO 99/42856).

DE 44 12 770 A1 discloses that overlapping antenna lobes may be produced for a motor vehicle distance-warning radar in which the beam lobes may also be swiveled. Either an exciter system is used there as the transmitting and receiving antenna, or a separate transmitting and receiving antenna is provided.

WO 02/15334 discloses a multi-beam antenna array having a beam-shaping network and a beam-combining network. Measures are taken there to have the transmitting and receiving lobes point in exactly the same direction.

### Advantages of the Invention

The measures of Claim 1, i.e., two radar sensors for the determination of distance and angular deviation each having a separate transmitting and receiving antenna, receiving antennas for the two radar sensors switchable with reference to their main beam direction as well as to their beam width, and an evaluation means for obtaining the angular deviation from the receiving signals of the two radar sensors in unlike switching states of their receiving antennas, allow the number of radar sensors, in particular for the determination of angular deviation, to be reduced. Two different receiving

antenna characteristics give information concerning the angular deviation of a target.

In addition to the evaluation of angular deviation using only two radar sensors, an increase in range is obtained.

Switching, i.e., free selection of antenna characteristics with reference to their main beam direction and beam width, results in great flexibility for a variety of applications, e.g., ACC, TWD, PP, in the close and far range. When the additional antenna exciter arrays are switched off, the antenna system is still capable of delivering its usual performance.

Advantageous embodiments are described in the subclaims.

#### Drawings

Exemplary embodiments of the present invention are explained with reference to the drawings.

Figure 1 shows a radar sensor having a transmitting and a receiving antenna array in each instance;

Figure 2 shows an antenna characteristic in the azimuth direction for transmitting and receiving antenna;

Figure 3 shows a variety of target scenarios with switchable antenna characteristic of a receiving antenna;

Figure 4 shows a target situation with antenna characteristics of three radar sensors without switching of the antenna characteristics;

Figure 5 shows the target situation of Figure 4 using two radar sensors with switching of the antenna characteristics;

Figure 6 shows antenna characteristics with two switchable radar sensors and antenna characteristics pointing outward with reference to the receiving antenna having a narrow beam width;

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Figure 7 shows a radar sensor with alignment of the antenna characteristics having a narrow beam width in the direction of the sensor axis;

10 Figure 8 shows antenna characteristics of two arrays of patch antennas, and

Figure 9 shows the design of a patch antenna array and the signal evaluation.

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#### Description of the Exemplary Embodiments

Figure 1 shows a known antenna arrangement having a column 1 of four patch exciters for transmitting and a column 2, separate therefrom, of four patch exciters for receiving. A single patch exciter has a beam angle of about  $90^\circ$ .

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If, as here, a plurality of patches, for example four patches, are located in a column, the vertical antenna beam angle (elevation) is reduced by the number of antenna elements. With the four patch exciters of Figure 1, a vertical beam angle of  $30^\circ$  is obtained. In the horizontal direction (the azimuth), nothing is altered with respect to a single exciter, i.e., the beam angle is  $90^\circ$ . The antenna characteristics associated with Figure 1 are shown in Figure 2. The antenna characteristics for transmitting and receiving in the azimuth are practically the same.

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Now, if one or more columns are combined into one receiving-antenna array, beam shaping may also be executed in the azimuth. The antenna diagram may be swiveled when the

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individual columns are in addition controlled separately by signals displaceable in phase. For this purpose, phase shifters 3 with unlike time lags may be provided for each column (Figure 9, whose output signals are processed together in evaluation unit 4, in order to determine the angular deviation from the receiving signals of the two radar sensors in unlike switching states). Switch-off or switch-on of antenna columns may likewise be varied in the antenna diagram, i.e., the antenna characteristic. Two columns that are capable of being switched on and have four patch exciters each are shown in Figure 9.

Switching the receiving antenna characteristics allows the number of radar sensors to be reduced. Two different receiving antenna characteristics permit information concerning the angular deviation of a target to be obtained. Various target scenarios are shown in Figure 3. Thus, in addition to distance information, the angular deviation is obtained. The switchable antenna diagrams of the receiving antennas for separation of the two targets are shown in Figure 3.

Figure 4 shows the ACC-stop-and-go situation using three radar sensors without antenna switching. At least three radar sensors 5, 6, and 7 are required in order to be able to react specifically to two targets using triangulation.

Figure 5 shows the same situation, controlled according to the present invention by two radar sensors 8 and 9, specifically by designing the receiving antennas of radar sensors 8 and 9 as switchable with reference to their main beam direction as well as to their beam width, in particular by switching antenna columns 2, 21, 22 on and off (Figure 9) and corresponding phase control. The two narrow lobes, i.e., the antenna characteristics having a narrow beam width, are swiveled out of the sensor axis, i.e., toward the midperpendicular of the two radar sensors, in the direction of

the center of the vehicle. An increase in range directly in front of the vehicle is thereby obtained.

The following advantages of the arrangement in Figure 5 as compared with the arrangement in Figure 4 are obtained:

- Rough angular resolution of a single sensor,
- Reduction in the number of radar sensors,
- Increase in range,
- Switching, i.e., free selection of the antenna characteristic, results in greater flexibility (ACC, TWD, PP).

The antenna columns are switched on or off depending on the application. When additional columns are switched off, the radar sensors continue to be capable of delivering the same performance, as can be seen in Figure 2. There a variation of the known amplitude monopole method is shown with antenna lobes that are not swiveled.

The case with lobes turned outward with reference to the narrow beam widths is shown in Figure 6. This arrangement permits precise detection at the edges of the vehicle path in forward as well as in reverse direction. It is of course alternatively possible to align the narrow antenna lobes in the direction of the sensor axis (Figure 7). The same advantage as described above is obtained by skillful selection methods. Two targets can be specifically allocated in combination with the second radar sensor (Figure 8). The increased gain of the antenna increases the range of the radar sensor. In addition, switching of the antenna characteristics (lobes) permits optimal use of the radar sensor in the close range and in the far range. The antenna characteristic remains constant, so that the transmitting power need not be switched. This might possibly be necessary for approval reasons.

As Figure 9 shows, the receiving antenna has an array of individual patches. Triggering of the antenna columns gives information concerning the mode of operation. Either the signal phases are switched and a swivelable antenna lobe is present, or the columns are switched on and a distinct change in the beam angle of the receiving antenna is present.

The antenna system according to the present invention is advantageously suitable for angular resolution in pulse radar applications of automotive technology, but alternatively may advantageously be used for other applications.